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POST OFFICE BOX X
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**ORNL**
**CENTRAL FILES NUMBER**

ORNL/CF-80/320

DATE: October 22, 1981

SUBJECT: RADIOLOGICAL SURVEY AT SELECTED LOCATIONS IN NIAGARA FALLS, NEW YORK

TO: Distribution

FROM: W. D. Cottrell, B. A. Berven, and F. F. Haywood

ABSTRACT

This report contains the results of a radiological survey of selected locations in Niagara Falls, New York. These locations include: 93rd Street School, 99th Street School, 66th Street School, Niagara Falls Catholic School, and the South Section of Love Canal. The survey was performed at the request of the Director of the Environmental and Safety Engineering Division at the Department of Energy (DOE Headquarters). Results indicate that several locations in Niagara Falls contain areas of low-level contamination (15 to 20 times background) that were once or are presently asphalted with a bedding of rock-slag material (cyclowollastonite) that probably originated from an electrochemical process that used uranium-bearing raw materials. It is also possible that some of this material has been mixed with other rock and gravel and used as fill or for purposes of surface stabilization.

CONTENTS

## INTRODUCTION

At the request of the Director of the Environmental and Safety Engineering Division, Department of Energy Headquarters, a series of radiation measurements and soil radionuclide analyses were made at five locations in Niagara Falls, New York. The purpose of this brief investigation was to assist the New York State Department of Health (NYSDH) in determining the type and magnitude of radioactivity present at these locations, to determine if the radioactivity at these locations was the result of contract activities by the former Manhattan Engineer District (MED) or Atomic Energy Commission (AEC), and to determine if a formal survey would be recommended.

The survey was performed by F. F. Haywood and W. D. Cottrell of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL) and D. A. Dooley of the NYSDH (Love Canal and 99th Street School on September 23, 1978, and 93rd Street School on August 23, 1978, and September 9, 1978). Results from these earlier surveys indicated that elevated external gamma-exposure rates and low-level radioactive contamination were present at these locations.[1,2] This survey was performed at those three locations in support of the NYSDH findings. During the present survey of these three locations, requests were made by local residents to perform additional surveys at the 66th Street School and the Niagara Falls Catholic School. Survey results at these additional two locations are included in this report. Soil and rock samples were also obtained and analyzed from three other locations: middle gate entrance of Hooker Chemical Company on 102nd Street; inside furnaces at the former Oldbury Electrochemical Company at 47th Street and Buffalo Avenue; and LaSalle Junior/Senior High Schools on 76th Street and Buffalo Avenue.

## RADIOLOGICAL SURVEY METHODS

Several methods were used to characterize the radiological status of these sites. A portable survey meter with an attached NaI scintillation probe was used to determine external gamma-exposure rates. Measurements were made at 1 m above ground surfaces. Surface and/or subsurface

soil and rock samples were dried, pulverized and radionuclide content was determined from gamma spectrometry analyses using a Ge(Li) detector (see Appendix I). The $^{238}U$ concentration was determined by neutron activation by the Analytical Chemistry Division at ORNL.[3] Mineral content of the soil and rock samples (petrographic analyses) was determined by X-ray diffraction performed by Bendix Field Engineering Corporation of Grand Junction, Colorado.

For purposes of comparison, background levels for external gamma exposure rates range from 5 to 10 μR/hr.[4] Concentration of $^{226}Ra$ in soil samples taken from this region range from 1.1 to 3.6 pCi/g (NFS13 and NFS14, Table 1). The only applicable federal guidelines relative to the ORNL radiological survey measurements performed at these sites are for continuous exposure to gamma radiation to an individual in the population (whole body).[5] Gamma exposure rate, according to these guidelines, may not exceed 60 μR/hr.

## 93rd Street School Site

In previous surveys, elevated external gamma exposure rates were found at a vacant lot south of the school property.[2] Levels as high as 60 μR/hr were observed. Thirteen soil and rock samples, taken at various depths, were obtained from five sampling locations (see Fig. 1) and analyzed for radionuclide content. Soil samples were taken at locations 1, 2, 4, and 5 (11 samples) where elevated external gamma exposure rates were observed. Two soil samples were obtained at location 3 where external gamma exposure rates were near normal background levels. Samples taken from locations 1, 4, and 5 were sent to Bendix for petrographic analyses.

## 99th Street School Site

This area was located within the Love Canal area, and was previously surveyed by the NYSDH.[1] Nine soil and rock samples, taken at various depths, were obtained from five sampling locations (see Fig. 2) and analyzed for radionuclide content. All five sampling locations were selected where elevated external gamma exposure rates were observed.

Soil and rock samples were collected at locations 7, 8, and 9 in the grassy area where run-off from the adjacent pad collected. Silt was collected at location 10, which was the lowest point on the asphalt pad. Asphalt, rock, and soil were collected at location 6. Samples from locations 6 and 7 were sent to Bendix for petrographic analyses.

## 66th Street School Site

External gamma exposure rate measurements were taken at this site. The site was traversed at approximately 50-ft intervals, and the average and maximum levels were recorded. Soil and rock samples were not taken at this site at the time this survey was performed; however, on November 12, 1978, D. A. Dooley obtained two samples from the locations indicated in Fig. 3 and sent them to ORNL for radionuclide analyses.[2]

## Niagara Falls Catholic School Site

A walk-over external gamma radiation survey was performed at this site. This school is located one block south of the 66th Street School. Soil and rock samples were not taken at this site at the time this survey was performed; however, on November 12, 1978, D. A. Dooley obtained a rock sample at the location indicated in Fig. 4 and sent it to ORNL for radionuclide analyses.[2]

## Love Canal - South Section

In previous surveys by NYSDH,[1] elevated external gamma exposure rates were found at various locations in the Love Canal. During this survey, several external gamma exposure rate measurements were made at the south end of Love Canal. A rock and soil sample was taken from location 11 at this site (see Fig. 5). This sample was also sent to Bendix for petrographic analyses.

## Other Locations

Location 12. A rock sample was collected on September 11, 1978, at the middle gate entrance of Hooker Chemical Company on 102nd Street (see Fig. 5). Radionuclide and petrographic analyses were performed on this sample.

Location 14. A slag sample was obtained from inside the furnaces at Oldbury Electrochemical/Hooker Chemical Company at 47th Street and Buffalo Avenue in Niagara Falls. This sample, collected by D. A. Dooley[2] and sent to ORNL on November 12, 1978, for radionuclide analyses, was sent to Bendix for petrographic analyses.

Location 18. A rock sample from LaSalle Junior/Senior High Schools at the corner of 76th Street and Buffalo Avenue in Niagara Falls was collected by D. A. Dooley and sent to ORNL for radionuclide analyses on November 12, 1978.

# SURVEY RESULTS

## 93rd Street School Site

Results of radionuclide analyses of soil and rock samples are listed in Table 1. The "background" samples at location 3 (see Fig. 1) contained $^{238}U$ and $^{226}Ra$ concentrations of 1 to 3 pCi/g. Other locations had concentrations up to 18 times background for these radionuclides. Bendix petrographic analyses of samples NFS-16 (location 4) and NFS-22 (location 1), were identified as cyclowollastonite ($CaSiO_3$) (see Table 2). An example of X-ray diffraction results of a typical sample composed of cyclowallastonite from a Niagara Falls location is compared to two diffraction standards in Table 3. Sample NFS-18 (location 5) was also analyzed by Bendix, who identified the sample as sandstone (see Table 2).

## 99th Street School Site

Results of radionuclide analyses of soil and rock samples are listed in Table 1. Locations 6 and 7 (see Fig. 2) had $^{238}U$ and $^{226}Ra$ concentrations that were up to a factor of 18 times that of background concentrations for $^{238}U$ and $^{226}Ra$. Locations 8, 9, and 10 had concentrations of

$^{238}U$ and $^{226}Ra$ that were not significantly different from background levels, however, a soil sample at location 8 had $^{137}Cs$ concentrations of 15 pCi/g (typical background concentrations are less than 1 pCi/g for $^{137}Cs$ in New York). Locations 7, 9, and 10 also contained significantly higher concentrations of $^{137}Cs$. Bendix petrographic analyses of samples NFS-3 (location 6) and NFS-9 (location 7) identified their predominant mineral content as cyclowollastonite (see Table 2).

66th Street School Site

Results of external gamma exposure rate measurements are illustrated in Fig. 3. Readings as high as 30 to 40 μR/hr were observed at specific locations on the asphalt pad adjacent to the school.

Results of radionuclide analyses of soil and rock samples are listed in Table 1. Sample NFS-27 (location 15) had $^{238}U$ and $^{226}Ra$ concentrations that were approximately a factor of 18 times background concentrations and soil sample NFS-28 had a $^{137}Cs$ concentration of 4.0 pCi/g.

Niagara Falls Catholic School Site

External gamma exposure rate measurements resulted in radiation levels as high as 50 μR/hr at specific locations. Results of radionuclide analyses of the rock samples NFS-29A and NFS-29B taken at location 17 (see Fig. 4) are listed in Table 1. A concentration of 46 pCi/g of $^{226}Ra$ was determined for NFS-29A and the $^{238}U$ concentration was 51 pCi/g. These values were roughly 17 times the background concentrations of these radionuclides.

Love Canal - South Section

External gamma exposure rates were as high as 50 μR/hr at specific locations. Radiation readings were comparable to specific locations at other sites surveyed (i.e., Niagara Falls Catholic School, 66th Street School). The activity appeared to be associated with rocks scattered over and imbedded in the soil.

Results of radionuclide analyses of the soil and rock sample taken at location 11 (see Fig. 5) are listed in Table 1. Concentration of $^{226}Ra$ and $^{238}U$ were both 46 pCi/g in sample NFS-24. Bendix petrographic analyses of sample NFS-24 identified the predominant mineral as cyclo-wollastonite (see Table 2).

## Other Locations

Location 12. Concentrations of $^{226}Ra$ and $^{238}U$ were 35 and 38 pCi/g, respectively, at NFS-24 (see Fig. 5. for location and Table 1 for results). These values are significantly above background concentrations for these radionuclides. The rock sample contained $^{137}Cs$ concentrations of 3.5 pCi/g.

Location 14. Concentrations of $^{226}Ra$ and $^{238}U$ were 54 and 53 pCi/g, respectively, at NFS-26 (see Table 1). Bendix identified the predominant mineral as psuedowollastonite ($CaSiO_3$) in sample NFS-26 (see Table 2).

Location 18. Concentrations of $^{226}Ra$ and $^{238}U$ were 55 and 60 pCi/g, respectively, at NFS-30 (see Table 1).

## DISCUSSION

Some soil and rock samples collected at these sites (including five schools and Love Canal) had concentrations of $^{226}Ra$ and $^{238}U$ 15 to 20 times typical background concentrations (see Table 1).

Locations showing elevated levels of external gamma radiation (factors of 5 or 6 above background and equaling NRC guidelines) and high $^{226}Ra$ and $^{238}U$ concentration in the soil and rock samples were associated with either asphalted areas (parking lots and playgrounds) or locations with numerous broken rocks on or near the soil surface. Two locations not covered by asphalt were in the vacant lot adjacent to 93rd Street School and the south section of Love Canal. It was determined that the 93rd Street site had previously been a government housing project with numerous asphalted parking areas. The asphalt was removed, leaving the gravel bedding underneath. The Love Canal was a filled area and had received fill material from various sources. The rock samples adjacent to and immediately beneath the asphalt at the 99th Street School, the

66th Street School, and Niagara Falls Catholic School were similar in appearance to those found at 93rd Street School and at the south section of Love Canal. It may be concluded that the contaminated material found on this survey was used for gravel bedding underneath several areas that were asphalted at some earlier period in Niagara Falls history.

Essentially all of the contaminated rock samples at these sites had the same concentrations of $^{226}Ra$ and $^{238}U$ (see Table 1). The $^{226}Ra$ and $^{238}U$ concentrations in all of the soil and rock samples were either at background (1 to 3 pCi/g) or between 35 to 55 pCi/g. This suggests that the rocks probably originated from a singular source. Also, it may be observed that the concentration of $^{238}U$ and $^{226}Ra$ in each sample was approximately equal. This indicates that $^{238}U$ and $^{226}Ra$ are nearly in secular equilibrium. It seems that whatever the source of these rocks, they may not have been involved in uranium or radium recovery processes.

It was observed that these contaminated rocks at all the sites surveyed were similar in appearance by having what appeared to be voids as if from gas bubbles. Petrographic analyses (see Table 2) revealed the predominant mineral from contaminated samples was cyclowollastonite (psuedowollastonite). This mineral is a synthetic compound often found as a waste material, namely slag, from thermal processes for production of elemental phosphorous. The voids in the samples are characteristic of slag material from furnaces. Cyclowollastonite-psuedowollastonite is formed at temperatures above 1200° C from wollastonite.

The sample (location 14 – NFS-26) obtained from the furnace at the Oldbury Electrochemical Company (presently owned by Hooker Chemical Company) was similar in appearance, radionuclide concentration, and mineral content to other samples obtained at the other sites surveyed. This may suggest this location as a possible source of the contaminated material, but evidence for this conclusion could only be circumstantial.

Samples NFS-1 (location 10) and NFS-7 (location 8) at the 99th Street School site had elevated concentrations of $^{137}Cs$ (8.4 and 15 pCi/g, respectively). Typically, background concentrations of $^{137}Cs$ are less than 1 pCi/g in the New York State area, however, values of 15 to 18 pCi/g of $^{137}Cs$ have been observed in other areas of the United States in background samples. Location 10 was in an area where the asphalt had sunk

with time and had become bowl-shaped in the center with run-off accumulating in the area; a silt sample was taken from this depression. Location 8 was approximately 1 ft from the asphalt pad adjacent to the bowl-shaped depression; this sample came from the top 4 in. of soil.

The elevated $^{137}Cs$ concentrations noted at locations 8 and 10 are believed to be due to the long-term accumulation of fallout deposited on the asphalt pad and subsequent washoff to these locations. Although fallout data for the Niagara Falls Area were not available, estimates of fallout deposition for that latitude were used to calculate the accumulation of fallout on the asphalt pad and the subsequent concentration of $^{137}Cs$ in adjacent soil (locations 8 and 10). These calculations were made assuming: 85 $mCi/km^2$ to be the integrated deposition of $^{90}Sr$ in the 40° to 50° latitude band from tests up to but not including 1975[5]; a mean $^{137}Cs/^{90}Sr$ yield ratio of 1.6[6]; an approximate mean decay time of 12 years based on significant fallout accumulation commencing in 1954; and an asphalt pad size of 80 m × 30 m. Further, assuming that all the fallout was washed from the pad and was uniformly absorbed on the soil contained in a strip 30 centimeters wide, 30 centimeters deep, and 60 meters long (the approximate length of the area that would receive washoff from the pad), the resulting concentration of $^{137}Cs$ in the soil would be approximately 27 pCi/g. Accounting for less than 100% washoff from the pad and that the normally irregular deposition pattern of fallout prevails, the 8 to 15 pCi/g range of $^{137}Cs$ concentration observed in soil appears reasonable.

## CONCLUSIONS

It may be concluded that:

1. There are several locations in Niagara Falls that are contaminated with a rocky-slag material primarily comprised of cyclowollastonite (psuedowallastonite). These locations are associated with areas where the slag material was used as fill.
2. The contaminated material probably came from a singular source where uranium-bearing ores were used, but the

uranium-radium was not separated out, such as that found in a phosphate separation operation.

3. Cyclowollastonite, a synthetic material, possibly originated from an electrochemical process using cyclowollastonite in conjunction with uranium-bearing raw materials and was similar to that found in the furnaces at Oldbury Electrochemical Company (now Hooker Chemical Company), which was once involved in production of elemental phosphorous using thermal processes.
4. It is highly unlikely that the low-level contaminated material found at various locations around Niagara Falls is related to MED/AEC activities at the former Oldbury Electrochemical Company since this material probably migrated from a chemical process unrelated to those conducted under MED/AEC contracts.
5. Under present land-use conditions, the contaminated material at these properties do not pose any significant increase in risk from potential health effects. However, if land-use conditions change, a potential for increased exposure to radiation (therefore increased risk of contracting cancer) may exist.
6. The elevated $^{137}Cs$ concentrations in several samples are probably associated with worldwide fallout which may have accumulated in certain areas.

It is recommended in light of the above conclusions that a formal radiological survey be conducted at these properties. However, this radiological survey is not necessarily the responsibility of the DOE since the radioactive materials present at these properties are probably not the result of contract activities by the MED/AEC.

## REFERENCES


1. J. M. Matuszek, "Interim Report on Radiological Surveys at the Love Canal," Radiological Sciences Laboratory, Division of Laboratories and Research, New York Department of Health, September 5, 1978.
2. D. A. Dooley, letter to F. F. Haywood with attachment, Interim Report, RE: Niagara Falls — 93rd and 66th Street Schools Site Surveys and Soil Sampling, September 18, 1978.
3. F. F. Dyer, J. F. Emery, and G. W. Leddicotte, *Comprehensive Study of the Neutron Activation Analysis of Uranium by Delayed Neutron Counting*, Oak Ridge National Laboratory, ORNL-3342 (October 1962).
4. B. A. Berven, R. W. Doane, F. F. Haywood, and W. H. Shinpaugh, *Results of Ground Level Radiation Measurements in Support of the 1978 Aerial Survey of the Lake Ontario Ordnance Works, Lewiston, New York*, ORNL/TM-7004 (September 1979).
5. Nuclear Regulatory Commission, "Standards for Protection Against Radiation," *Code of Federal Regulations*, Title 10, Part 20.
6. *Health and Safety Laboratory Environmental Quarterly*, HASL-318, December 1, 1976, through March 1, 1977.
7. U. S. Department of Energy, *Radiological Survey of the Hooker Chemical Company, Niagara Falls, New York*, DOE/EV-0005/2 (January 1977).

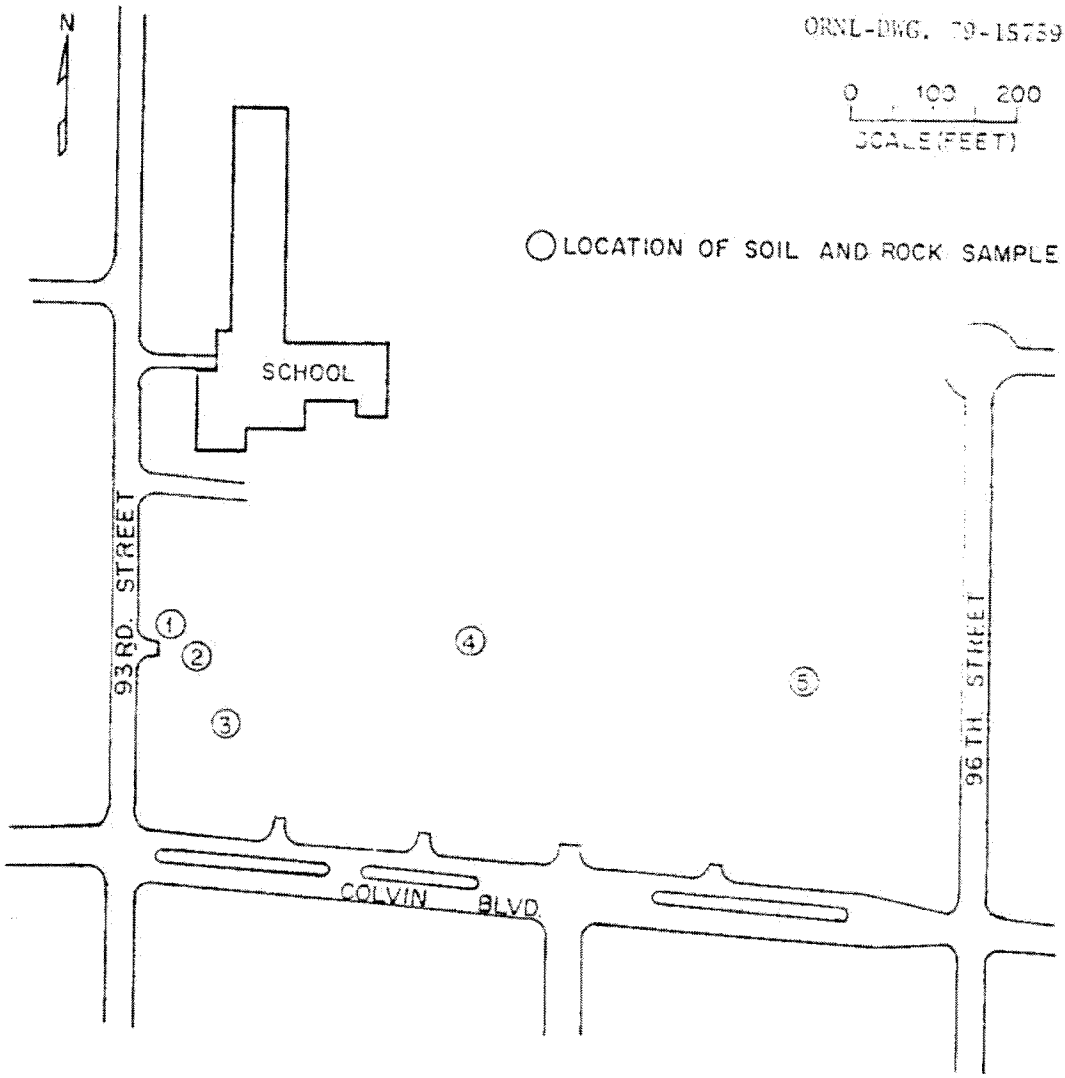


Fig. 1. Location of soil and rock samples at 93rd Street School site.

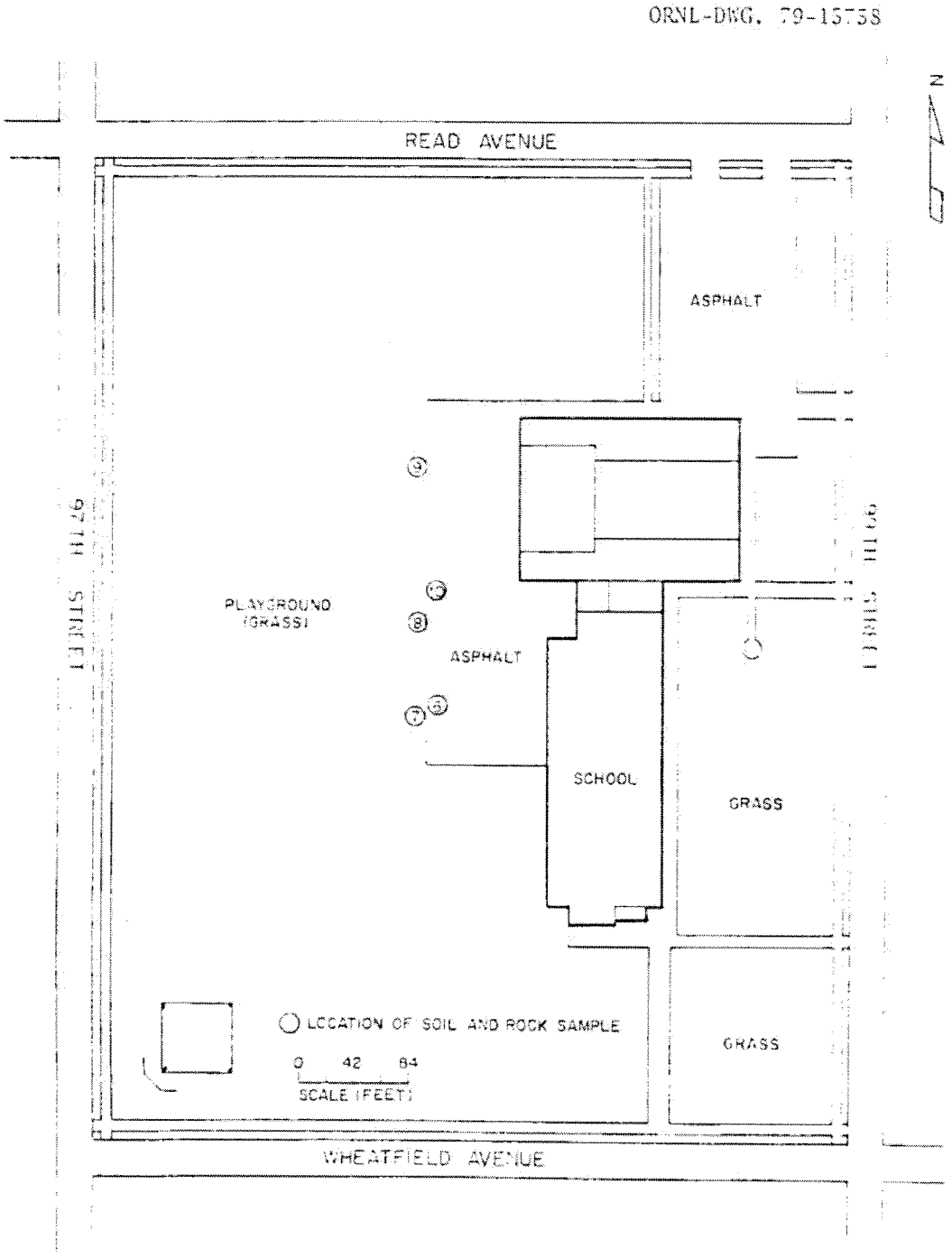


Fig. 2. Location of soil and rock samples at 99th Street School site.

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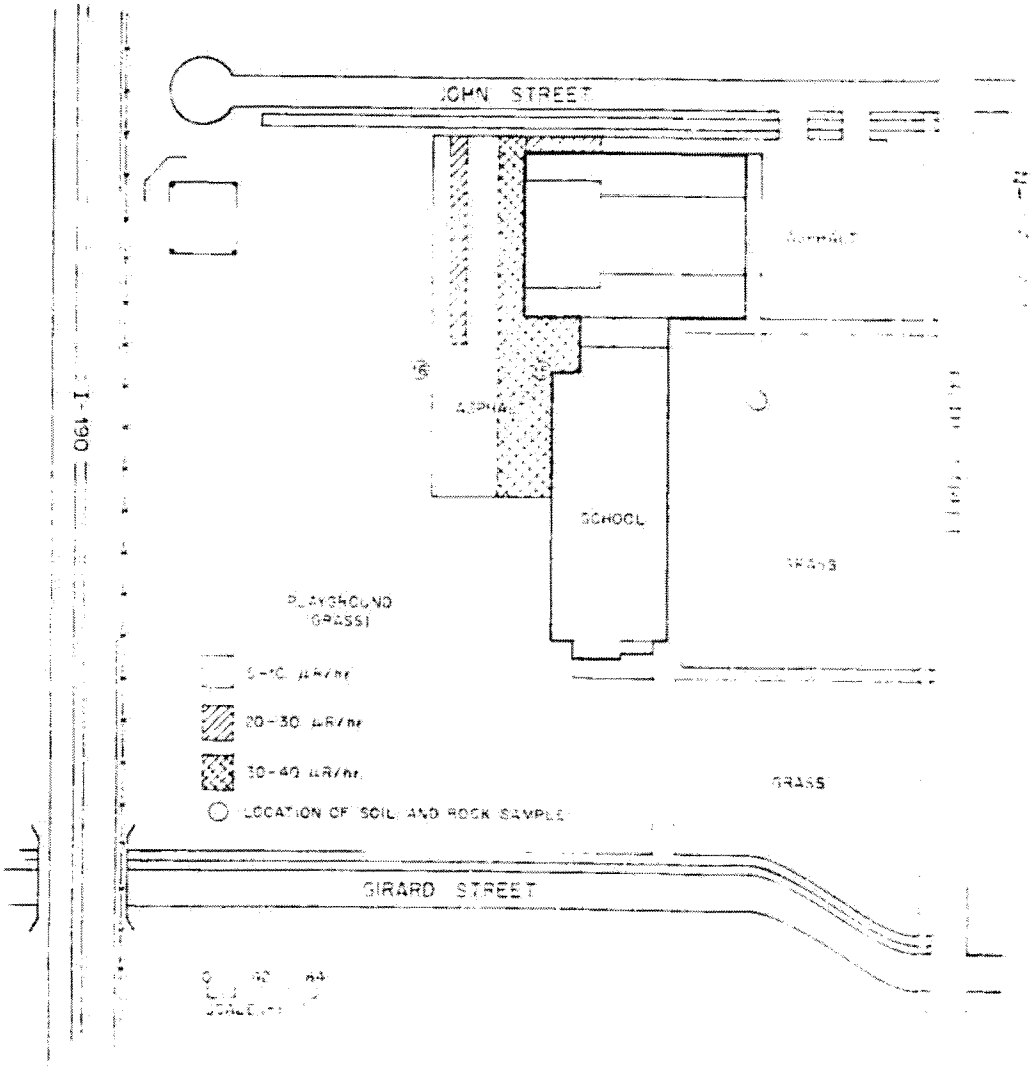


Fig. 3. External gamma exposure rate measurements and soil and rock sample locations at the 66th Street School site.

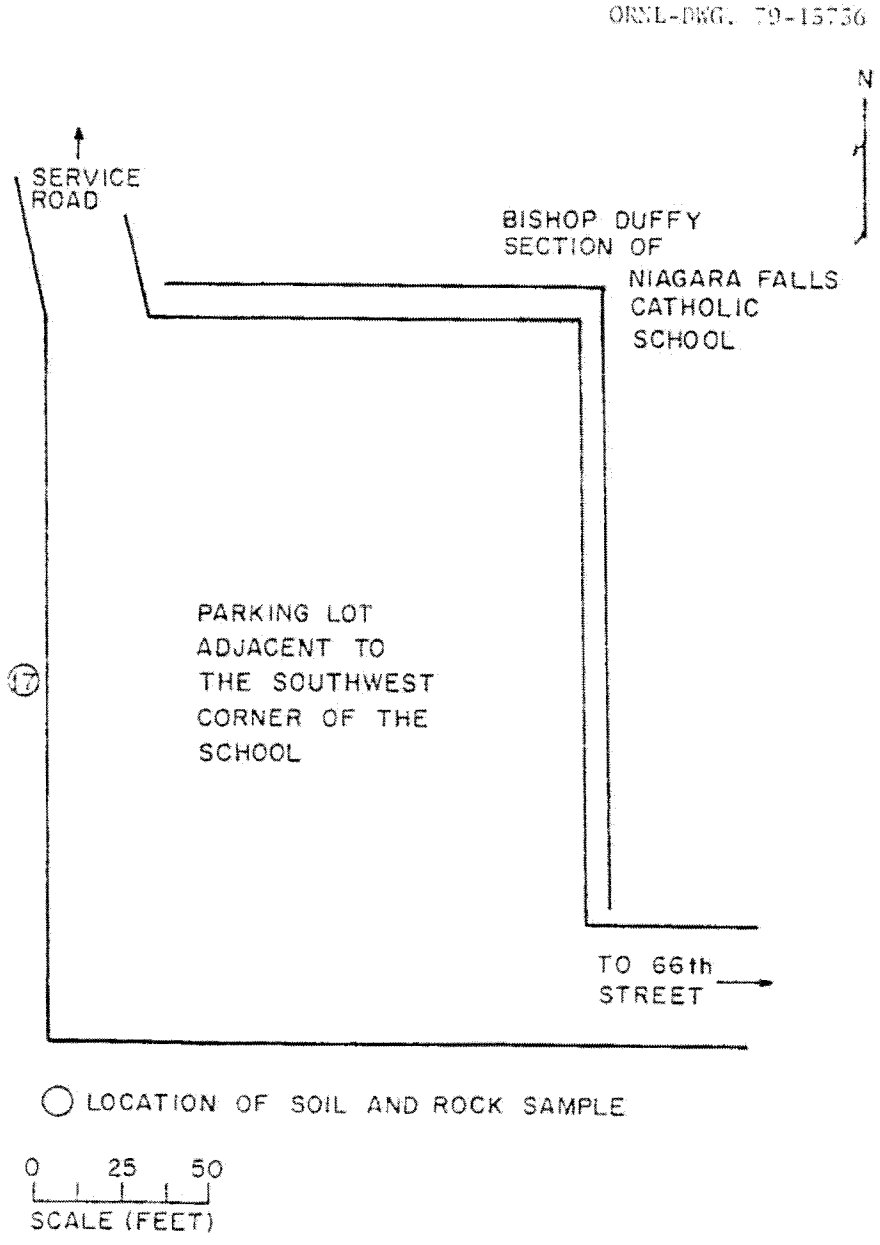


Fig. 4. Location of soil and rock sample at Niagara Falls Catholic School site.

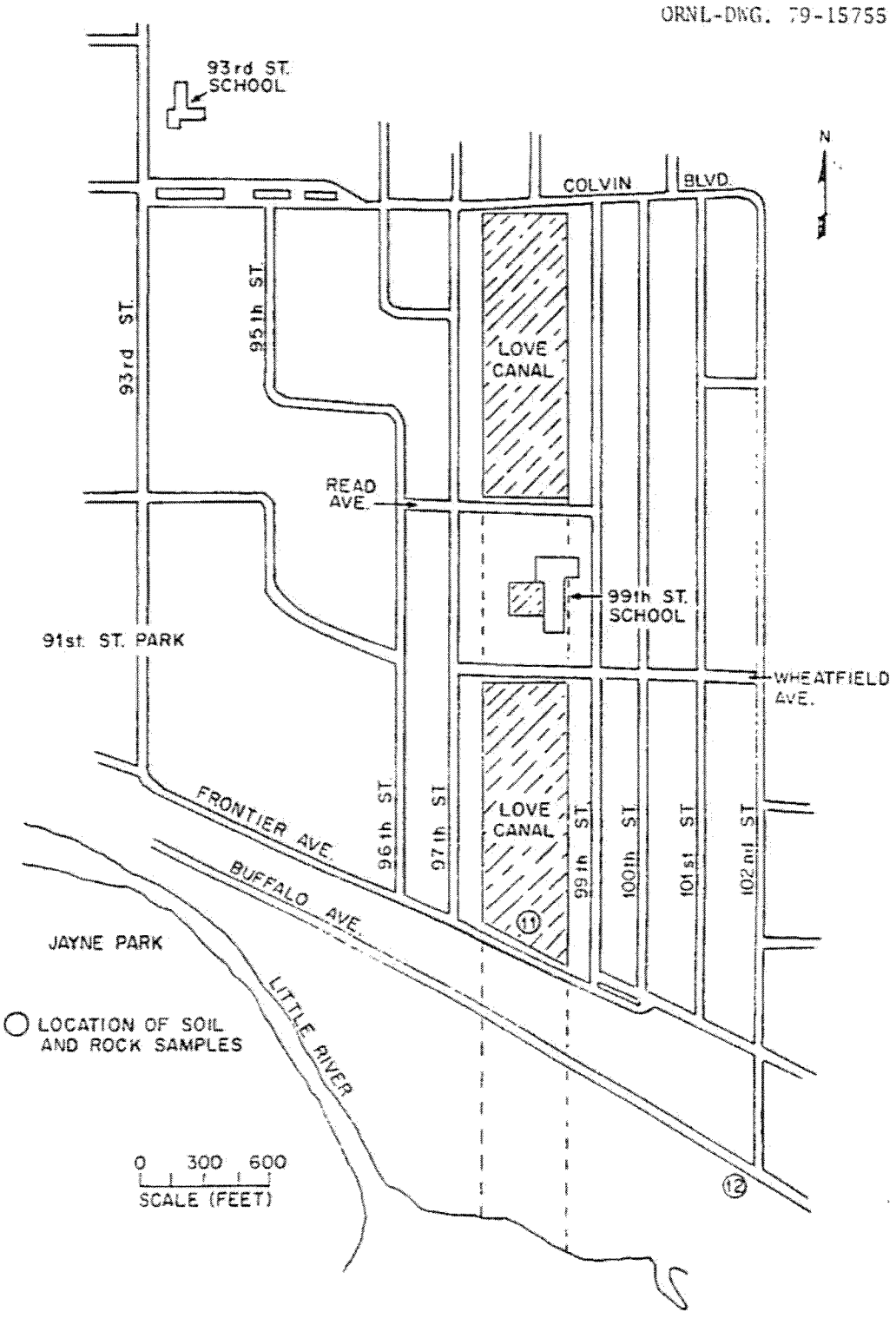


Fig. 5. Location of soil and rock sample at Love Canal site and on 102nd Street.

Table 1. Concentration of $^{226}Ra$, $^{238}U$, and $^{137}Cs$ in soil and rock samples from Niagara Falls, New York

| Sample location | Sample No. | Sample type | Depth (in.) | Radionuclide concentration (pCi/g)[a] $^{226}Ra$ | $^{238}U$ | $^{137}Cs$ |
|---|---|---|---|---|---|---|
| 1 (93rd Street School) | NFS-10 | soil | surface | 42 ± 0.60 | 45 | b |
| | NFS-22[c] | rock | surface | 55 ± 1.0 | 60 | b |
| 2 (93rd Street School) | NFS-11 | soil | surface | 41 ± 0.80 | 48 | b |
| | NFS-12 | soil | 0-18 | 3.8 ± 0.04 | 4.3 | b |
| 3 (93rd Street School) | NFS-13 | soil | surface | 3.6 ± 0.04 | 3.1 | 0.12 ± 0.01 |
| | NFS-14 | soil | 18 | 1.1 ± 0.05 | 0.99 | 0.24 ± 0.02 |
| 4 (93rd Street School) | NFS-15 | soil | surface | 3.7 ± 0.52 | 4.1 | b |
| | NFS-16[c] | rock | 4 | 54 ± 0.80 | 52 | b |
| | NFS-17 | soil | 30 | 1.7 ± 0.04 | 1.7 | b |
| 5 (93rd Street School) | NFS-18[c] | rock | surface | 46 ± 0.60 | 46 | b |
| | NFS-19 | soil | surface | 16 ± 0.20 | 17 | b |
| | NFS-20 | soil | 20 | 5.3 ± 0.04 | 5.7 | b |
| | NFS-21 | soil | 40 | 1.5 ± 0.04 | 1.7 | b |
| 6 (99th Street School) | NFS-2 | asphalt | 0-3 | 4.0 ± 0.08 | d | b |
| | NFS-3[c] | rocks | 3-6 | 51 ± 0.60 | 52 | b |
| | NFS-4 | soil | 10-12 | 6.8 ± 0.20 | 6.7 | b |
| | NFS-5 | soil | 30 | 1.0 ± 0.20 | 1.0 | b |
| 7 (99th Street School) | NFS-6 | soil | 0-4 | 1.1 ± 0.05 | 1.4 | 2.1 ± 0.60 |
| | NFS-9[c] | rock | 4-6 | 48 ± 0.40 | 48 | b |
| 8 (99th Street School) | NFS-7 | soil | 0-4 | 1.1 ± 0.09 | 2.9 | 15 ± 1.1 |
| 9 (99th Street School) | NFS-8 | soil | 0-4 | b | 2.8 | 3.1 ± 0.20 |
| 10 (99th Street School) | NFS-1 | silt | surface | 0.50 ± 0.70 | 1.5 | 8.4 ± 0.60 |
| 11 (Love Canal) | NFS-24[c] | rock | surface | 46 ± 0.50 | 46 | b |
| 12 (102nd Street) | NFS-25[c] | rock | surface | 35 ± 0.50 | 38 | 3.5 ± 0.10 |

Table 1. (continued)

| Sample location | Sample No. | Sample type | Depth (in.) | Radionuclide concentration (pCi/g)[a] $^{226}Ra$ | $^{238}U$ | $^{137}Cs$ |
|---|---|---|---|---|---|---|
| 13 e | e | e | e | e | e | e |
| 14 (Oldbury Furnace) | NFS-26[c] | rock | δ | 54 ± 0.40 | 53 | b |
| 15 (66th Street School) | NFS-27 | rock | 4-7 | 54 ± 0.80 | 56 | b |
| 16 (66th Street School) | NFS-28 | soil | 0-5 | 1.2 ± 0.06 | 1.2 | 4.0 ± 0.08 |
| 17 (Niagara Falls Catholic School) | NFS-29A | rock | 4-7 | 46 ± 0.30 | 51 | b |
| | NFS-29B | rock | 4-7 | 1.8 ± 0.03 | 2.1 | 1.0 ± 0.09 |
| 18 (LaSalle Junior/ Senior High School) | NFS-30 | rock | 4-7 | 55 ± 0.50 | 60 | b |

[a] Indicated errors associated with these concentrations are 1.96 sigma (95% confidence).

[b] Concentration of radionuclide was below detection limits.

[c] Petrographic analyses performed.

[d] Analyses not performed.

[e] Location 13 was a sample sent to ORNL from an unidentified location.

[δ] Sample was collected inside the furnace.

Table 2. Results of petrographic analyses of selected samples from Niagara Falls, New York

| Sample location | Sample No. | Identification of predominant mineral[a] |
|---|---|---|
| 1 (93rd Street School) | NFS-22 | cyclowollastonite[b] |
| 4 (93rd Street School) | NFS-16 | cyclowollastonite |
| 5 (93rd Street School) | NFS-18 | sandstone |
| 6 (99th Street School) | NFS-3 | cyclowollastonite |
| 7 (99th Street School) | NFS-9 | cyclowollastonite |
| 11 (Love Canal) | NFS-24 | cyclowollastonite |
| 12 (102nd Street) | NFS-25 | cyclowollastonite |
| 14 (Oldbury Furnace) | NFS-26 | psuedowollastonite[b] |

[a]Analyses performed by Bendix Field Engineering Corporation in Grand Junction, Colorado.

[b]Chemical composition: $CaSiO_3$.

Table 3. X-ray diffraction results of a typical[a] sample with standards for mineral identification

| Sample NFS-24 | | Diffraction standard: Cyclowollastonite[b] 19-248[c] | | 10-486[c] | |
|---|---|---|---|---|---|
| d-Spacing Å | $I/I_1$ | d-Spacing Å | $I/I_1$ | d-Spacing Å | $I/I_1$ |
| 5.68 | 15 | 5.67 | 60 | 5.87 | 10 |
| | | | | 5.73 | 40 |
| 5.16 | 10 | | | 5.16 | 20 |
| 4.37 | 15 | 4.37 | 50 | 4.39 | 40 |
| 3.79 | 7 | 3.76 | 30 | 3.75 | 20 |
| 3.43 | 25 | 3.42 | 70 | 3.41 | 40 |
| 3.24 | 100 | 3.23 | 100 | 3.20 | 100 |
| | | 3.21 | 100 | | |
| 2.81 | 90 | 2.81 | 70 | 2.79 | 80 |
| 2.71 | 10 | 2.70 | 30 | 2.69 | 10 |
| 2.45 | 20 | 2.44 | 70 | 2.46 | 60 |
| 2.36 | 10 | 2.37 | 30 | 2.35 | 20 |
| 2.23 | 10 | 2.22 | 30 | 2.21 | 20 |
| 2.19 | 7 | 2.18 | 30 | 2.17 | 20 |
| 2.00 | 20 | 1.99 | 70 | 2.05 | 10 |
| 1.98 | 80 | 1.97 | 100 | 1.96 | 80 |
| 1.84 | 20 | 1.85 | 60 | 1.83 | 30 |
| 1.72 | 10 | 1.71 | 30 | 1.71 | 10 |
| 1.69 | 15 | 1.68 | 30 | 1.68 | 30 |
| 1.62 | 20 | 1.61 | 30 | 1.60 | 30 |
| 1.54 | 15 | 1.52 | 30 | 1.53 | 10 |
| 1.48 | 20 | 1.47 | 50 | 1.49 | 60 |
| 1.41 | 12 | 1.40 | 30 | 1.40 | 30 |

[a] Taken from a letter to ORNL dated October 19, 1978, from Bendix Field Engineering Corporation, Grand Junction, Colorado.

[b] $CaSiO_3$.

[c] File number of standard from Joint Committee on Powder Diffraction Standards.